V.—HEREDITY AND SEX.

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In the previous section (this JOURNAL, III, 97–114) we found that not only did the problem of heredity involve psychic or metaphysical elements, but that a rational explanation of the facts of heredity is possible if such psychic powers are assumed to lie at the foundation of the whole matter. The reactions of living protoplasm to the stimuli of the environment are most easily understood, or at least designated, if we use terms familiar to the student of purely mental phenomena, such as, "association" of ideas, "memory," "education," etc.

Reproductive cells are to be considered as similar to the protozoa, but with a more complicated education, their offspring knowing how to associate themselves into the form of an organism, in which each cell, while inheriting all the knowledge of its parent, finds itself choosing a specific occupation, determined by conditions of which we are as yet ignorant. In this statement possibly lies a harmonization of the Kölliker and the Weismann views. The cytoplasm is undoubtedly differentiated, but it does not follow that the idioplasm is so also, although the training this idioplasm receives becomes more and more special as development proceeds. *Reproduction in its widest sense* is nearly equivalent to nutrition, and consists in the multiplication of idioplasm molecules, that is, the growth of protoplasm, by which ordinary food particles become organized, related, and subservient to the forms of motion peculiar to the specific kind of protoplasm, whatever it may be. *Actual cell reproduction* is a secondary adaptation resulting from the limitations of nutrition, and dependent ultimately upon assimilation. *Ordinary reproduction*, as we know it, is the multiplication of the individual organism, and is a tertiary acquirement. It follows that the problem of heredity in its widest sense involves that of assimilation as its physical side. This use of the term heredity includes all that lies at the basis of biology and psychology.

But so far, the idea of sexuality is not necessarily involved in the theory of heredity, and it must be admitted that a careful study of the evolution of sex in the lower forms of life shows that sex is an acquired characteristic, useful for certain purposes, such, for example, as the securing of variation. The fundamental fact of sex is the uniting of idioplasms, usually accomplished by the fusion of cells produced in two different organisms. These cells are mostly unlike, as is often the case also with the cell-producing individuals; and our idea of sex is attached to this third differentiation. But sometimes both kinds of cells are produced by one individual, which is then hermaphrodite or "bisexual." But there is here no double individuality, the hermaphodite being as singly an individual as any animal, and properly has no sex whatever.

Students of heredity are familiar with the idea of the character of one sex lying "latent" in, or "transmitted" by, the opposite sex. A little thought will show that this phenomenon is exactly the same as that above noted, when we supposed all the cells of the body to have the same idioplasm, but only special portions of the cell knowledge ever to come to application or development. The idioplasm in each cell of a male of a species does not differ materially from that in the cells of the corresponding female, but is "hermaphroditic," to use an abused and misunderstood term. In a similar way the idioplasm of a nutritive zooid of a hydroid colony is similar to that of a defensive or of a reproductive zooid.

Just as everything in biology may be considered as growing out of assimilation by differentiation of primitive methods and organs for securing nutrition, so everything in psychology has likewise been evolved out of the psychic forces that we may suppose needful to secure

a primitive act of assimilation, all the while remembering that the psychological side of the fact is the deeper or more significant. An elaboration of these two sciences along the lines of natural development as thus indicated remains to be made, and for biology can fairly be said to have begun.

In this introduction we have merely suggested certain general foundations upon which the facts brought out in the following reviews may rest in a related manner. The facts will be treated in the following order: First, the sexual phenomenon among the protozoa and the relation of these to the phenomenon of fertilization are considered, to show that sex is a secondary specialization. We next inquire how such secondary differentiation is brought about and as to our ability to control the production of the sexes. Then follows a consideration of the significance of menstruation, leading us naturally into the larger field of physiological and psychological periodicity. Next we take up the subject of ecstasy and of the perversions of the sexual instinct. Then the field offered by anthropological and social facts is outlined, including mythological phenomena. Finally we conclude with pedagogical, hygienic, and other practical aspects of the question, especially family life.

For a consideration of sex among the unicellular animals, consult the following works: *Significance of Sex*, Nelson, Amer. Naturalist, Jan., Feb., Mar., 1887, (noted in the first section of our review). *La vie psychique des micro-organismes*, Binet (noted in first section). *L'instinct sexuel chez l'homme et chez les animaux*, Tillier (noted below). The general facts are presented by the second and third of these authors; the first presents special facts to prove that "sex" as it is ordinarily understood cannot apply to the cells, but only to the gametaphores or the higher organisms. But the author further shows that the fundamental thing which caused the development of sex is the union of idioplasms of diverse experience, but of similar morphological or hereditary education; and this union, he thinks, is not only illustrated by conjugation of cells, but also by the phenomena of karyokinesis which precedes the division or multiplication of cells. The author does not wish it to be understood that he dogmatically denies the existence of a true "sexual" (in a broad sense of the word) differentiation of protoplasmic gemmules (plastidules), but that the facts, so far as we have them, are explicable on a simpler assumption.

Almost all unicellular organisms that are not parasites, exhibit at times the phenomenon termed *conjugation*, *i. e.*, two cells melt together to form one, in a manner very different from what happens when one cell eats another. With some of the ciliated infusoria the cells are united only temporarily while a mutual interchange of nuclear material takes place. In all cases a new cell nucleus is formed, consisting of material from two different cells. With the vorticellas the nucleus buds off microspores that become the fertilizing elements of some other macrospore, and then (itself having become a macrospore) is fertilized by a microspore from some other individual which is preferably not in the same colony with itself. Here it looks as if there were two sorts of protoplasm, the ordinary vorticella being hermaphrodite; but in other cases the entire cell splits up into microspores, or into macrospores; and in still other cases there is no difference in size or appearance between the conjugating cells. What happens in the case of vorticella is clearly an adaptation useful to a sessile condition. The difference between a macrospore and a microspore is seen to be mainly in the amount of cytoplasm present; the nuclei in the majority of cases are equal. This difference may be readily accounted for when we reflect that the microspore must be a swimming organism, and must find the

macrospore, largely by chance, in a large volume of water, hence a great number of microspores must be produced.

In the case of the metazoa conjugation is always secured by the fertilization of a macrospore (ovum) by a microspore (spermatozoon). When the former is utilized as a storehouse for nutriment (yolk or deuteroplasm) for the developing embryo, the size (as in the case of the hen's egg) becomes relatively enormous, but the amounts of idioplasm that unite are approximately equal, and represent in each case all the characters of the species, including those that are peculiar to each sex. That conjugation is not an absolutely necessary occurrence is shown by the fact that if it is prevented the egg often develops as if it had occurred, and in many instances parthenogenesis is normal, as in the plant lice; and furthermore, in some of the lowest plants, where the embryo is very simple and does not require the large store of deuteroplasm, even spermatic parthenogenesis occurs, especially in the case of microspores of the algæ.

Thus we are excluded from the hypothesis that there are two sorts of protoplasm, the union of which, is needful for life. But what is the significance of conjugation (or fertilization)? Evidently the idioplasms of the two cells have had different experiences. The chances are that many cells have "gone to the ground" while this experience has been acquired, and that if each cell before conjugation had to encounter the trials the other has surmounted, it might succumb. How easy to unite the two experiences and enlarge the life. "Two heads are wiser than one," is the law even among the protozoa. Hermaphroditism is usual with sessile organisms like mollusks and barancles; and is understood to be an adaptation to a fixed condition, mutual fertilization being advantageous. When the ova are fertilized while yet in the body and the spermatozoa are conveyed to them the production of a smaller number of fertilizing cells is required. A further advance is possible by substituting for a large yolk, the uterine gestation of the embryo. These advances cause the acquirement of special organs that become the external signs of sexual differentiation, both psychological and physiological. To apply the idea of sex to the cells is misleading. Even the human embryo is hermaphrodite (properly non-sexed), and rudiments of the organs of the opposite sex are present in all animals. In cases of monstrosities these rudiments suffer more or less of development as may be seen by consulting "*L'hermaphrodisme*" by Debierre.

If sex is caused by secondarily acting extraneous forces, it becomes an important inquiry to investigate what such forces are, and how they act. This has been done in the most able manner by the following author.

Die Regulierung des Geschlechtsverhältnisses bei Vermehrung der Menschen, Tiere und Pflanzen. DÜSING. Jena, 1884, pp. 364.

There appears to be a fixed ratio between the number of male and female births which in many instances approaches equality. For man this ratio is 106 boys to 100 girls. What circumstances cause this ratio to vary? The reproductive organs are very sensitive to variations in the amount of food, and it is of advantage to a species to accommodate the number of offspring to the supply of food available. The number of offspring depends primarily on the number of females, hence there must exist an association between the tendency to the production of ova and the fact of increased food supply if any regulation of this sort is present. Facts show that such is the case. In general terms the law may be stated thus: good nutrition and moderate exercise of the reproductive organs produces a tendency to the production of females, while poor nutrition and excessive exercise of these organs produces a tendency to the production of males. The eggs of the queen bee receiving